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TISSUE DAMAGE AFTER TRUNK INJECTION OF GROWTH REGULATORS INTO SILVER MAPLE TREES

Report No 91-178-K

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ABSTRACT

Silver maple trees, which had been trunk injected with the growth regulators flurprimidol and paclobutrazol in 1985, were harvested in 1990 and examined for bark splits, bark cracks, and staining (discolouration) of the wood. No link could be demonstrated between application of the growth regulators and/or the methanol carrier and the incidence of splits, cracks and stained wood. In all trees 7% or less of the surface area of the 2 m section of trunk examined was covered with splits and cracks. Similarly 22% or less of the total 2 m section volume was occupied by stained wood. The effects of splits, cracks and stained wood on the health of trees should be investigated further.

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EXECUTIVE SUMMARY

TISSUE DAMAGE AFTER TRUNK INJECTION OF GROWTH REGULATORS INTO SILVER MAPLE TREES

G.P. Arron

The trimming of trees under or beside distribution lines on city streets and in rural areas is a major expense for utilities in North America. Such operations are conducted at intervals of one to eight years depending on the individual species growth rate and the amount of line clearance required. Growth regulators such as paclobutrazol, flurprimidol, and uniconazole have been shown to inhibit the growth of woody species. Treatment of the trees under distribution lines with such growth regulators might reduce both the frequency of trimming and the time taken to trim. A popular method of application of such products is trunk injection. This method is superior to other methods in that the amount applied is precise, chemical contact with non-target plants is prevented, and environmental residues are reduced.

From 1985 to 1989 a field project was conducted at Wesleyville GS in which silver maple trees were trunk-injected with paclobutrazol or flurprimidol. Growth of the trees was inhibited over the four growing seasons. There have been reports that bark splits and stained wood are found in trees that have been trunk-injected with growth regulators. In the present study trees from the Wesleyville GS experiment were harvested in early 1990 and the bottom 2 m of each trunk examined for bark damage and stained wood. There was considerable variation in the number and area of bark splits per tree, and in the area of each split, for trees treated with paclobutrazol, flurprimidol, and methanol alone (the carrier in which the growth regulators were applied), and for untreated trees. Similar large variations were found in the number and area of branch splits and cracks per tree, and in the volume of stained wood in each tree. Much of the stained wood was found in the bottom 1 m section of the trunks, where the trees had been injected in 1985 and had cores removed in 1988 (to estimate tree ring growth). For all the parameters examined no significant effect was observed for the various treatments (paclobutrazol, flurprimidol or methanol alone). In light of the facts that bark splits, branch

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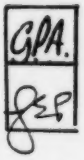
splits and cracks, and stained wood are found naturally in silver maple, and there is considerable variation in the number, area, or volume of these parameters from tree to tree, many trees would have to be examined to determine the effect of trunk injection of growth regulators on such parameters.

More information is required on the effects of trunk injection of growth regulators on the bark of all trees, since such a method could only be used as part of a tree trimming program if the overall health of the trees was not jeopardized. Stained wood in treated trees would also be of interest, since it is not known if such areas cause problems when the trees are reinjected. It is not known whether the application of growth regulators in the form of capsules would avoid the issues of bark damage and wood staining.



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TO: Dr. D. Mills
Director of Research

TISSUE DAMAGE AFTER TRUNK INJECTION OF GROWTH REGULATORS INTO SILVER MAPLE TREES

1. INTRODUCTION

The trimming of trees under and beside distribution lines on city streets and in rural areas is a major problem and expense for North American utilities. Such operations are conducted at intervals of one to eight years depending on the individual species growth rate and the amount of line clearance required. Several new growth regulators, such as paclobutrazol, (PP 333) ((2RS, 3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,3-triazol-1-yl)pentan-3-ol), flurprimidol, (EL - 500), (a-(1-methylethyl)-a-(4-(trifluro-methoxy)phenyl)-5-pyrimidine-methanol), and uniconazole, (XE 1019), ((E)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol)-1-penten-3-ol), have been reported to control excessive sprout growth in a number of woody species (Miller, 1982; Hare, 1984; Arron, 1985, 1986a, 1986b, 1989a, 1990; Sterrett, 1985, 1988; Sterrett and Tworkoski, 1987). Treatment of trees under distribution lines with such growth regulators might reduce both the frequency of trimming and the time taken to trim. A popular method of applying these products is by trunk injection, which has advantages over other methods (such as foliar spray, bark banding, soil drench or soil injection) in that the amount applied is precise, chemical contact with non-target plants is prevented and environmental residues are reduced (Sterrett, 1988).

After application with a methanol carrier, paclobutrazol, flurprimidol, and uniconazole are translocated upwards via the xylem into the stem and foliage, while movement downwards into the roots is minimal or not detected (Richardson and Quinlan, 1986; Wang et al., 1986; Sterrett, 1985, 1988, 1990; Sterrett and Tworkoski, 1987; Early and Martin, 1988; Arron, 1990).

In the last fifteen years many trees in North America have been injected with such products in experiments and in regular vegetation control operations (by utilities such as Philadelphia

Electric, Potomac Edison, Florida Power and Light, and Puget Sound Power and Light). Bleeding from the holes (sometimes called weeping or fluxing) have often been reported after injection, and certain species are more prone to this problem than others (for example see Curley, 1988; Arron, 1989a). There have been reports that after injection of paclobutrazol, uniconazole and atrinal, trunk cankers appear (Houde, 1988; Watson, 1988; Wright and Moran, 1989). Cankers include raised areas of bark, open lesions (bark splits) in which cambium dieback had occurred, and internal injuries (such as stained wood) or compartmentalization. Discoloured or stained wood is due to the oxidation of a variety of phenolics and these products deter the growth of wood-decaying fungi, often excluding their growth while the external wound calluses (Shigo and Sharon, 1970; Wright and Moran, 1989). Such cankers usually appear around the third year post injection or later (Potomac Edison, 1990). Watson (1988) reported that 14.5% of the over 8,000 injection holes made by Potomac Edison in 1984-85 resulted in bark splitting, caused by the death of a section of the cambium layer near the injection hole while the surrounding cambium continued to grow. The carriers used, methanol and isopropanol, killed the cambium tissue, with more bark splits occurring when holes were drilled in dormant months when transpiration rates were low.

Wright and Moran (1989) reported that following the injection of Norway maple (Acer platanoides L.) trees with Atrinal (dikegulac sodium or sodium 2,3 : 4,6 di-o-(1-methylethylidiene)-L-xylo-2-hexulofuranosonic acid) in water the average volume of compartmentalization (i.e. the percentage of stained wood within 10 inches of injection point) was correlated with both the size of external cankers and the percentage of the crown that was removed at trimming . Stained wood has also been reported in largetooth aspen (Populus grandidentata Michx.) injected with uniconazole in either methanol or isopropanol (Houde, 1988). Studies by this latter author demonstrated that the stained wood was caused by the alcohol carrier and not by the growth regulator itself, an observation confirmed by Potomac Edison (1990). Wright and Moran (1989) indicated that there is good evidence that wood decay occurs when trees fail to heal wounds or when compartmentalized areas (i.e. stained wood) are rewounded. This would occur when trees were reinjected, perhaps three or four years after the first injections. There have been no reports on the response of trees to repeated injections (a study has just been started by P. G. & E.). Trunk cankers, as well as bleeding injection holes (Curley, 1988; Arron, 1989a), may make the injection of growth regulators into particular species (e.g. Norway maple) unacceptable from an aesthetic point of view.

In the present study, the response of silver maple (Acer saccharinum L.) trees to trunk injection with either paclobutrazol or flurprimidol in methanol was examined. The trees, which were injected in May 1985 as part of a growth inhibition study (see

Arron, 1989a), were harvested in early 1990. Growth was inhibited by both growth regulators (Arron, 1989a). The trees were examined for stained (discoloured) wood, bark splits, and splits and cracks associated with branch insertions on the trunk.

2. MATERIALS AND METHODS

2.1 Plant Material

In a growth study, initiated in May of 1985, on the effects of growth regulators on sprout growth and increase in overall height, twelve year old silver maple trees (Wesleyville GS) had been trimmed and trunk injected with either paclobutrazol or flurprimidol. Measurements of growth had been taken from 1985 to 1988 (see Arron, 1986b, 1989a). Some of these trees were used in the present wounding study. The trees at the site were in rows 5 m apart, with 1.5 m between trees in a row. Trees which were diseased or had a large or small trunk diameter were excluded from the growth study. The trees had been divided into two groups, those with a single stem and those with two or three stems at the base of the tree. In the present wounding study, only some of the trees from the former group were examined. In the growth study the trees had been identified by row (A, B etc) and number (eg A1, A2 etc) and trees were selected for the present study in alphabetical order. Some trees had died and this meant only four trees could be harvested from each treatment group (ie a balanced design - with the exception of the paclobutrazol group). All trees in the growth study had been trimmed prior to injection, with about one third of their height being removed. The cut surfaces were not treated.

2.2 Trunk Injection

A solution of either paclobutrazol or flurprimidol in methanol had been prepared, containing 20 g a.i./L (active ingredient). In the original growth study (Arron, 1989a) seven single stemmed trees were injected with either paclobutrazol or flurprimidol. There were two control groups, one set of seven trees was injected with methanol alone (termed the methanol control trees), and the second set was not injected at all (termed the control trees). From each group of seven trees four were selected at random for the present study (with the exception of the paclobutrazol treated trees where only two trees were sampled). The volume of methanol or growth regulator solution to be injected into each tree was calculated using the formula:

$$\text{Volume} = (\text{DBH})^2 \times 0.492$$

(DBH = diameter at breast height)

Holes were drilled into the trunk of each tree between 15 and 30 cm from the ground using a hand drill with a 6 mm diameter bit. The holes were between 4 and 5 cm deep and were drilled at an angle of about 45 degrees to the trunk face, rather than straight into the tree (angle of 90 degrees). All trees had two injection holes. Solutions were injected into the trees using an Asplundh Tree Injector, with equal volumes being introduced into each hole. Initial pressure used was 621 kPa. Injection times varied from one to five minutes. All holes were plugged with silicone sealant to prevent pathogen entry. Tree cores were taken in the fall of 1988 from the south side of each tree at a point approximately 25 cm above the ground. (Information on the growth rings in the cores has been presented previously: Arron, 1989a).

2.3 Destructive Sampling of Trees

In the winter of 1989/1990, trees were cut down as close to the ground as possible. They were returned to the laboratory and cut into slices using a bandsaw. From the bottom of the trunk to a height of 1 m slices were cut every 2 cm, and from 1 m to 2 m, slices were cut every 5 cm. Each trunk cross section was immediately photocopied and the areas of the discoloured wood and of the section determined from the photocopies using a digitizer (Digital Paintbrush System). As the slices dried out the area of stain increased. Discoloured wood volumes were estimated by multiplying the area values by the thickness of the slice. Prior to sectioning, the surface of each 2 m trunk section was examined for trunk cankers. Trunk canker severity ranged from inconspicuous raised areas of bark to open splits or lesions in the bark where cambial dieback had occurred. The number, length and area of the bark splits and the splits and cracks associated with branch insertions on the main trunk were recorded.

3. RESULTS AND DISCUSSION

3.1 Appearance of Bark Splits after Trunk Injection

At harvest splits and cracks were observed on the trunk sections sampled. Some splits were found all over the trunk and these were called bark splits. Others occurred around the origin of branches on the main stem and these were called branch splits. Cracks were also associated with the branches (these termed branch cracks). In Table 1 information is presented on the number of bark splits observed per 2 m section of trunk, and their length and area. With the exception of the mean split length the values for number of bark splits per tree, area of bark splits per tree, and area of each bark split showed a great degree of variability, with in most instances a large range of values in each treatment. In all cases there was no significant difference between treated and control

trees (analysis of variance, ANOVA, conducted). For mean split length there was much less variability in the data, however again no significant differences between treatments were found. This suggests that drilling and injection of the growth regulators plus carrier had no effect on bark splits.

Similar results were obtained for branch splits and branch cracks, with a large variability in the data and no significant effect of treatment (data presented in Appendix 1). The area of trunk occupied by bark splits and branch splits was about the same, with branch cracks covering less area of the trunk. The area of trunk covered by splits and cracks combined was a small part of the total trunk area (about 7% or less of the total, see Appendix 1). In a study conducted for Potomac Edison it was reported that 46% of all trees (five species) injected with either paclobutrazol, flurprimidol, or uniconazole had bark splits which were 12 inches (30 cm) long or longer (Potomac Edison, 1990). These trees were larger than those in the present study and consequently were injected with larger volumes (up to 75 mL per hole) than used with the silver maple. If bark splitting is a result of the injection of alcohol, then larger splits may result from large volume injections. In large trees bark splits have been reported to occur directly above the injection points, with some damage around the hole and below it (Kimball, 1990). The alcohol would be located in these areas immediately after application, when there would have been some upward movement under the influence of the transpiration stream. Orr et al. (1988) reported that bark splits may not appear until several years after application and so trees will appear healthy until this time. Of the five species in the Potomac Edison study silver maple showed the least cambial damage (29% of trees), while up to twice as many black locust and black walnut trees showed cambial damage.

3.2 Appearance of Stained Wood after Trunk Injection

Examination of the various slices from the 0 to 2 m trunk sections revealed large areas of stained wood. At the lower end of the trunk it was possible to see the injection holes made in 1985 (and associated stained wood) and the core taken in 1988. Further up the trunk it became impossible to associate particular areas of stain with the injection holes or the core as the ribbons of stain up the trunk were not continuous, with some trunk sections having no stain at all. In addition some stained areas appeared to be associated with branch origins. As it was impossible to relate an area of stain to a particular wound the total area of stain on each section was measured. Since all the trees had been cored and had branch origins it was a question of relative amounts of stain in the trees from the treated and control groups. The volumes of stain found in the silver maple trees in the present study are presented in Table 2. The results are given for both the complete 0 to 2 m trunk section sampled and for the 0 to 1 m section. As was the case for

Table 1

Bark Splits in Trimmed Silver Maple Trees
Trunk Injected with Flurprimidol and Paclobutrazol

Treatment	Number of trees	-----Bark splits/tree (0 to 2 m section)----- Number		Length		Area		Area each split*	
		Mean	Range	Mean (cm)	Range (cm)	Mean (cm^2)	Range (cm^2)	Mean (cm^2)	Range (cm^2)
Control	4	5±2	3,6	9.5±1.6	7.2,10.5	73±18	53,94	17±8	11,28
Methanol Control	4	9±7	3,19	7.6±2.0	5.7,10.4	117±149	26,339	10±5	6,18
Flurprimidol	4	7±3	5,11	6.5±1.0	5.3,7.8	67±76	11,178	9±6	2,16
Paclobutrazol	2	13±16	2,24	8.7±1.2	7.8,9.5	106±118	23,190	10±2	8,11

*Mean value calculated for each tree and these values used to calculate mean given.

bark splits there was considerable variation in the stain data, both for stain volumes per tree (0 to 1 and 0 to 2 m trunk sections) and when the stain volumes were expressed as functions of the total 0 to 1 and 0 to 2 m trunk section volumes. This latter form of presentation may be the more informative because the trunk diameters and the injection volumes were different for each tree. There was no significant difference between the control and treatment groups (either a growth regulator plus methanol, or the methanol alone) as regards the volume of stained wood found. However for all four treatment groups most of the stained wood was found in the 0 to 1 m trunk section (ie close to the injection holes), with little being found in the 1 to 2 m section above this. The volumes of stained wood found in the present study (expressed on a % of trunk volume basis) are somewhat less than those reported earlier by Wright and Moran (1989) for Atrinal injections (from 8.7 to 15.0% for the 0 to 1 m sections, see Table 2, as against 20.3%). The volume of stain resulting from the injection of a methanolic solution is many times the volume injected. Injection volumes ranged from 10 to 37 mL while stain volumes ranged from 176 to 2283 cm^3 (for the complete stain data see Appendix 2), although a proportion of the latter will be as a result of the tree core taken in 1988. In a previous study the injection of 1.5 mL of uniconazole in isopropyl alcohol into silver maple saplings resulted in from 8 to 16 cm^3 of stained wood (Arron, 1989b). This manyfold increase in volume is the result of the alcoholic solution being diluted with sap after injection.

Table 2

Stained Wood in Trimmed Silver Maple Trees
Trunk Injected with Flurprimidol and Paclobutrazol*

Treatment	--0 to 1 m Trunk Section-- Total Stain Volume/Tree (cm^3)	Stain as % Section Volume	--0 to 2 m Trunk Section-- Total Stain Volume/Tree (cm^3)	Stain as % Section Volume
Control	455±213	8.7±2.0	531±195	6.0±0.9
Methanol Control	987±909	15.0±12.4	1137±1053	9.9±8.3
Flurprimidol	527±222	10.6±3.3	578±222	7.0±2.2
Paclobutrazol	1072±1009	11.0±6.3	1234±1153	7.4±4.3

*Values given are mean ± s.d.

Wright and Moran (1989) reported that the average canker (split) size in Norway maple trees injected with Atrinal was proportional to the amount (volume) of discoloured or stained wood. A linear regression analysis of the data from the present study, using the volume of stained wood and either mean area per bark split or mean area per crack and split (bark or branch) combined, revealed no significant correlation. There did appear to be some correlation between the volume of stained wood and the total area (per tree) of bark splits (r^2 value of 0.71). If staining of wood and cambial damage resulting in bark splitting are both caused by alcohol then it might be expected that the two parameters will be related. Total bark split length (per tree) also appeared to be correlated with stain volume (r^2 value of 0.87). Such relationships may be of some value since it is possible to measure bark splits easily while stained wood can only be estimated by destructive sampling.

Wright and Moran (1989) have suggested that the volume of stained wood underestimates the effective volume of compartmentalization. Their study raised an important issue in the use of growth regulators applied by trunk injection. Early studies by Shigo and Sharon (1970) revealed that the staining of wood is caused by the production of oxidation products, such as tannic and gallic acid, in the compartmentalized area. These compounds contain phenolic groups which stain the wood and are antimicrobial. By acting as deterrents to the growth of wood rot fungi, they allow callus tissue and new wood to heal over the wound. However these phenolic compounds are not as effective against other endemic fungi and bacterial species which grow slowly in the compartmentalized area and change the nature of the phenolic compounds. The problem arises when the compartmentalized areas are wounded a second time, and are then less well equipped to resist the invasion by true wood rot fungi. When trees are injected for a second time with growth regulators then this penetration of the compartmentalized area may occur and result in the tree being more prone to attack by wood rot fungi. The way in which the new injection hole is drilled will be important here, as a hole made at a shallow angle to the bark surface will penetrate the xylem little while a hole at right angles to the surface will penetrate deeply. It should also be remembered that from the time of the last injection to the reinjection, new xylem will have been formed and thus the initial wounds will be beneath several years xylem growth. Shallow reinjection holes may not reach them.

While the Wright and Moran (1989) study is the only examination of internal wounding caused by trunk injection of growth regulators published to date, it was not a thorough study. No control trees were examined to determine background levels of bark splits and wood staining, and no attempt was made to distinguish between the effect of the Atrinal and the carrier (water) in the injected solutions. In addition the study was limited to 10 trees of one species and therefore it would be premature to draw firm conclusions or to generalise about other species. The species

looked at, Norway maple, has been reported to respond poorly to injection, in terms of persistent bleeding from injection holes (Curley, 1988; Arron, 1990) suggesting a slow healing process which may indicate greater internal damage. In the study conducted by Potomac Edison (1990) no data was presented on bark splits and cambial damage in control trees.

The question of the effect of the trunk injection of growth regulators on the health of trees deserves greater attention, particularly since the same tree may be injected on a regular basis over many years. The long-term effects of growth regulators applied by capsules should also be investigated. In capsule application, holes are drilled on the trunk and capsules containing a water-soluble formulation of the growth regulator are inserted. Capsules avoid the use of organic carriers and high pressures to get the material into the tree but they do involve drilling holes in the tree in the same way as in trunk injection. There have been no reports published on the effects of such capsules on tree growth or any side effects.

Few studies have been reported on the effects of trunk injection of growth regulators on the bark and xylem of trees over the long-term because to examine the xylem the tree must be sacrificed. Few trees on city streets can be sacrificed. This means that such experiments are conducted in tree nurseries where the trees are younger than those found on city streets, they have not been trimmed repeatedly, and the growing conditions are generally better. Young trees grow at a faster rate than older trees, and they may be damaged more easily by the injection procedure.

4. CONCLUSIONS

1. In the five years after silver maple trees were trunk injected with methanolic solutions of the growth regulators flurprimidol and paclobutrazol various splits and cracks appeared in the bark. No link could be demonstrated between the appearance of such irregularities and the use of the growth regulators or the methanol carrier. In all the trees examined only 7% or less of the trunk surface was taken up with these splits and cracks.

2. Stained wood was also observed in the bottom 2 m section of trunks of these treated trees. While most of the stain was found at the bottom of the trunk, close to where injection holes had been made and the growth regulator solutions applied in 1985, and tree cores taken in 1988, no link was demonstrated between the appearance of stained wood and the application of the growth regulators and/or the methanol carrier.

3. It is not known what long-term effects such bark splits, cracks, and stained wood have on the health of the silver maple trees. While splits, cracks and stained wood occur naturally in trees in general, other studies have suggested that trunk injection of growth regulators does increase the incidence of bark splits and stained wood.

4. The trunk injection of such products will be introduced as part of an operational tree trimming program only when the responses of the various species to the treatment can be predicted. The treatment has to be acceptable to the public and the utility on the basis of aesthetic and many other considerations. Not enough information is available at present to support the introduction of such a treatment. The application method may be causing most of the present problems, and it might be useful to consider alternative methods such as the insertion of capsules.

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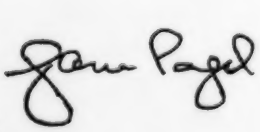

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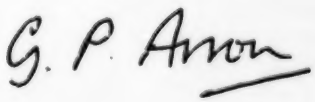

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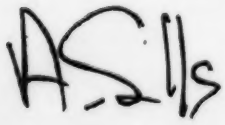

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Appendix 1. Splits and Cracks in Silver Maple Trees Trunk Injected with the Growth Regulators Flurprimidol and Paclobutrazol.

Treatment	---- Bark Splits/Tree --- Number Mean	Range	Area Mean (cm^2)	Range	-- Branch Splits/Tree -- Number Mean	Range	Area Mean (cm^2)	Range	- Branch Cracks/Tree - Number Mean	Range	Area Mean (cm^2)	Range	-All Splits + Cracks- Area/Tree Mean (cm^2)	Range	% Trunk Surface Range
Control	5±2	3,6	73±18	53,94	17±8	6,18	62±37	38,117	6±4	0,10	21±16	0,35	157±62	103,246	1.9,5.4
Methanol Control	9±7	3,19	117±149	26,339	10±5	2,10	68±49	28,138	6±5	2,14	24±23	4,57	208±151	72,399	1.5,7.3
Flurprimidol	7±3	5,11	67±76	11,178	8±6	4,11	116±72	45,193	5±4	2,10	26±21	7,52	209±140	90,380	2.3,5.8
Paclobutrazol	13±16	2,24	106±118	23,190	12±6	7,16	110±8	104,116	5±3	3,7	32±15	22,43	248±125	159,336	3.2,4.8

Appendix 2. Stain Volume in Silver Maple Trees Injected with the Growth Regulators Flurprimidol and Paclobutrazol

Treatment	Stain Volume: 1 m Trunk Section — Total Stain Vol. Mean (cm^3)	1 m Trunk Section — Total Stain Vol. Range	1 m Trunk Section — As % of Section Mean	1 m Trunk Section — As % of Section Range	2 m Trunk Section — Total Stain Vol. Mean (cm^3)	2 m Trunk Section — Total Stain Vol. Range	2 m Trunk Section — As % of Section Mean	2 m Trunk Section — As % of Section Range
Control	455±213	310,767	8.7±2.0	6.8,11.5	531±195	374,806	6.0±0.9	5.2,7.2
Methanol Control	987±909	176,2283	15.0±12.4	6.0,33.4	1137±1053	197,2644	9.9±8.3	4.2,22.2
Flurprimidol	527±222	350,819	10.6±3.3	6.1,13.6	578±222	370,877	7.0±2.2	3.8,8.6
Paclobutrazol	1072±1009	359,1786	11.0±6.3	6.5,15.4	1234±1153	419,2050	7.4±4.3	4.3,10.4